Announcements

1. Scientific notation is needed soon for HW. For example, an answer of 3.00 x 10^{8} would be submitted as 3.00e8, and 1.64×10^{-19} would be submitted as 1.64e-19, with no spaces.

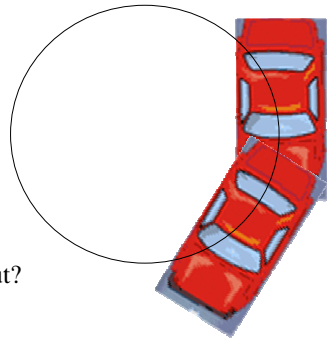
Failure of circular motion

Mud on wheel

Under what conditions will it fly off?

Demo: lazy susan

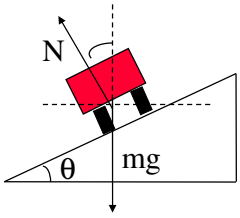
Sliding on seat in car



Is there a force pushing you out?
With no forces, you would…

What does the door do?

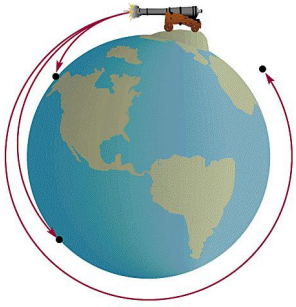
Why banked roadways?



Gravity

Classical physics was *invented* to understand motion of the planets:

Newton's thoughts about the moon's orbit and projectile motion about 1670



Parabola of projectile turns into a circle.

The apple, the Moon and the cannonball:

All are in _____

Newton's Law of Gravity: $F_G = G\frac{mM}{r^2}$

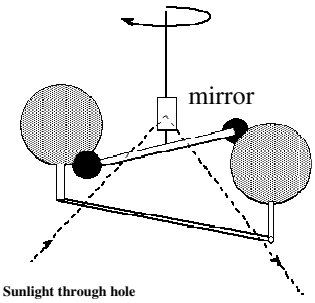
(sometimes with negative sign)

All masses attract all other masses!

1783: first measurement of forces between "regular" masses, by Cavendish.

$G = 6.67 \times 10^{-11}\ \mathrm{Nm^2/kg^2}$

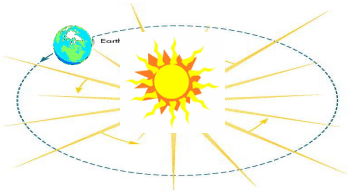
"weighing the world"



How did Newton know it was **inverse square**?

Kepler's laws (about 1600) came from observations of the planets in our solar system:

1. Elliptical orbits



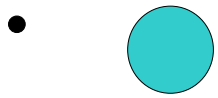
K

2. Equal areas in equal times:
greater speed closer to sun

3. The period^2 ~ r^3, or _____

#1 and 3 can happen only if F proportional to $\frac{1}{r^2}$

From the outside, a *spherical* mass (planet) acts as though its mass were all at _____.



If it were a spherical shell?

Drilling a hole through the earth…

Where does $g = 9.8$ m/s^2 come from?
g: "surface gravitational acceleration"

$R_{Earth} = 6371$ km
$M_{Earth} = 5.974 \times 10^{24}$ kg

What is g_{Mars}?

$R_{Mars} = 3390$ km
$M_{Mars} = 6.419 \times 10^{23}$ kg

(answer: a little more than 1/3 g_{Earth})

Orbital Velocity

On the moon (no air friction) you *could* get into orbit by pushing horizontally off the highest mountain.

How fast would you have to shoot someone?

"minimum orbital velocity"

How long would it take you to go around once?
"orbital period"

Circular orbits

For each v, only one r will work
For each r, only one v will work!

Satellites:
http://science.nasa.gov/RealTime/JTrack/3d/JTrack3d.html

International space station, R = 402 km + R_e
($r_e = 6.38 \times 10^3$ km) 7.67 km/s
Geosynchronous orbit, R=35.79×10^3 km + R_e
3.08 km/s
Moon's speed, average R = 384.4×10^3 km
1.02 km/s

Q4. Two satellites *A* and *B* of the same mass are going around Earth in circular orbits. The distance of satellite *B* from Earth's center is twice that of satellite *A*. What is the ratio of the tangential speed of *B* to that of *A*?

a. ½
b. square root of ½
c. 1
d. square root of 2
e. 2

Q5. The Moon does not fall to Earth because:

a. It is in Earth's gravitational field.
b. The net force on it is zero.
c. It is beyond the main pull of Earth's gravity.
d. It is being pulled by the Sun and planets as well as by Earth.
e. none of the above

Gravitational PE

Need new $PE_{gravity}$. PE=mgy just won't work…
Force isn't "mg" any more!

Using calculus… $\boxed{PE_G = -\frac{GMm}{r}}$

$PE_G = 0$ when r = _____

(no freedom to define zero of PE)

Escape Velocity

A bullet is shot straight up. What speed does it need in order to escape the earth? (ignoring air)
Think conservation of energy!

Answer: 11.2 km/s

Maneuvering in orbit: speed and total energy.

Higher orbits have more total energy, but less KE! If you want to have a **faster orbit**, you have to **throw away** energy with your rockets!

demo**:** gravity well

Q6. The place that we usually choose to be zero potential energy when doing orbit and rocket problems is

1. at the center of the earth
2. at the surface of the earth
3. infinitely far from the earth

Q7. You are on a planet that has a mass of 2× that of the earth, but its radius is 2× as big. You throw a ball at the surface, and find that g_{planet} is ___as g_{earth}

1. larger
2. smaller
3. the same

Q8. Did you discuss at least half of the discussion quiz questions today with a neighbor?

a. Yes b. No